1.1 Energy on Demand

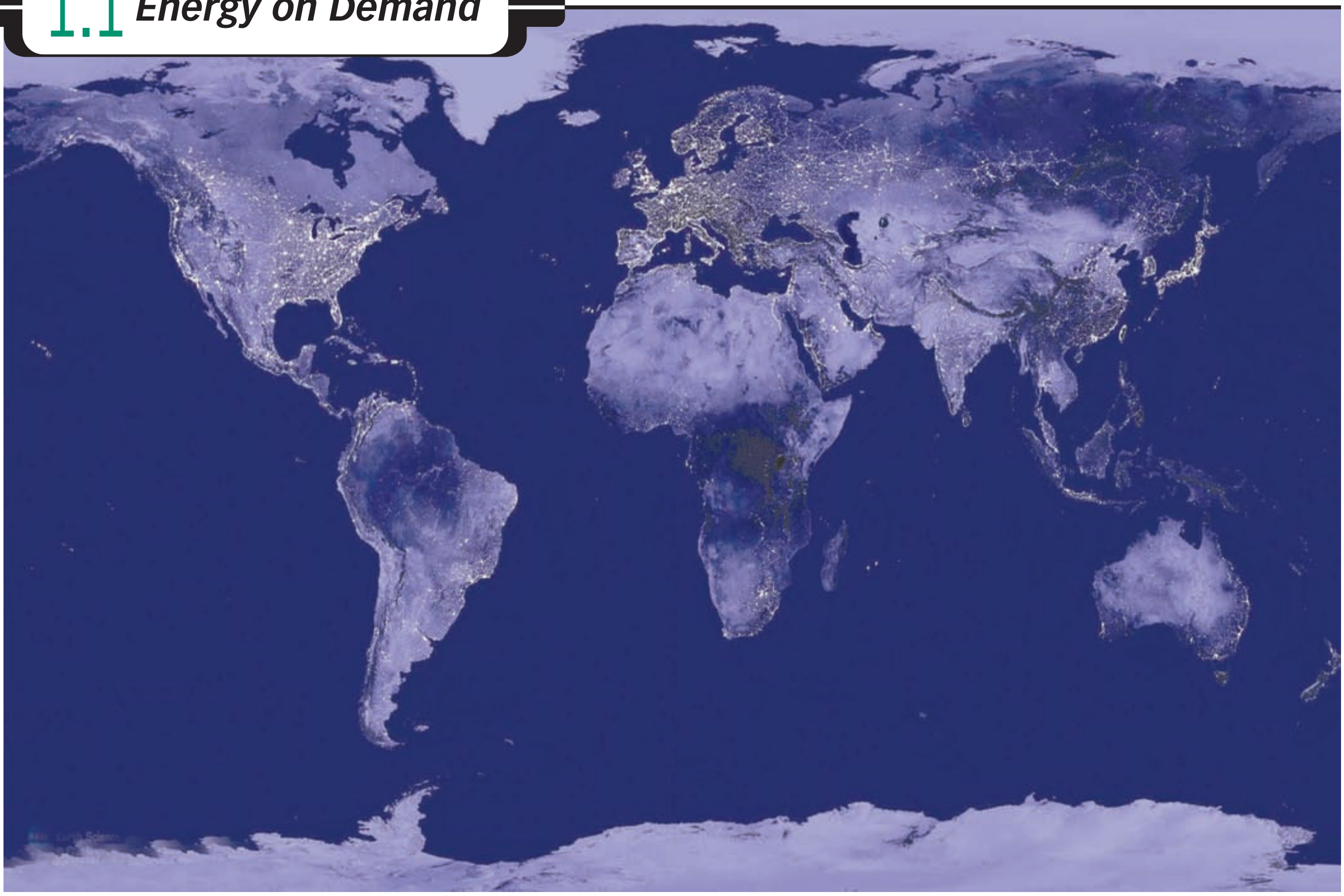


Figure D1.1: A composite of many satellite images shows light from cities across Earth that is visible from space.

Earth viewed at night from space shows a beautiful snapshot of energy use across the globe. Clusters of glowing cities dot the continents, revealing a planet transformed by human activity—activity that requires energy. Notice that some areas of the globe are not as bright as others. Is there a correlation between how bright an area appears in this photograph and energy use? How is a country's energy use affected by its level of development, economy, and climate? Imagine how this picture would change if developing countries were able to achieve the standard of living of developed countries.

Energy—The Currency of the Universe

energy: the capacity to do work

For anything to happen around you or even in your own body, **energy** is required. When you lift a grocery bag and place it on the kitchen counter, you expend energy in your muscles to do that work. Some of the chemical potential energy stored in your muscles is transformed into an increase in the gravitational potential energy of the bag and its contents. When somebody drives a car, the engine uses energy stored in the gasoline to do work. Some of the chemical potential energy stored in the molecules of gasoline is converted into the car's kinetic energy. When you turn on the lights in your home, electrical energy is used to do work, resulting in the release of radiant energy in the form of visible light and other forms of electromagnetic radiation. Even as you read this paragraph, the cells in your brain are working. They are using the energy stored in glucose molecules to carry out the functions of comprehending and establishing memories. All of this work takes energy. Every action has its energy price. Refer to the "Some Common Expressions for Energy" table for examples of units used to express energy.

DID YOU KNOW?

Food is a source of chemical potential energy. On average, 38.9 MJ are contained within 1 kg of fat compared to 17.2 MJ in 1 kg of carbohydrate and 31.5 MJ in 1 kg of gasoline.

SOME COMMON EXPRESSIONS FOR ENERGY

Unit	Symbol	Definition	Joules Equivalent	Example of Energy Involved
joule	J	energy needed to apply a force of 1 N over a distance of 1 m	1 J	Drawing a 25-cm line with a pencil on paper requires about 1 J of energy.
	TJ	terajoule	1×10^{12} J	This is equal to the energy stored in 24 tonnes of oil.
	PJ	petajoule	1×10^{15} J	This is equal to the energy stored in 24 000 tonnes of oil.
	EJ	exajoule	1×10^{18} J	This is equal to the energy stored in 24 million tonnes of oil.
calorie	cal	energy needed to raise the temperature of 1 g of water 1°C	4.19 J	A foraging hummingbird consumes about 15 cal of energy per second.
food calorie	Cal or kcal	energy needed to raise the temperature of 1 kg of water 1°C	4190 J	A human walking 33 steps consumes an average of 1 Cal.
British thermal unit	BTU	energy needed to raise the temperature of 1 pound of water by 1°F	1054 J	A typical barbecue has an energy output of 8 BTU for each second it operates.
kilowatt-hour	kW•h	equal to the work done by one kilowatt acting for one hour	3 600 000 J	This is equal to the work done during 5 h of vigorous cycling.

In the next activity you will explore the trends in world energy use, world population, and **per capita** energy use since 1850. These trends provide important background information for you to refer to throughout this unit.

per capita: for each person

Utilizing Technology

Trends in Energy Use

Purpose

You will use a spreadsheet to perform calculations and analyze data of world energy use.

Procedure

step 1: Open the "World Energy Use" spreadsheet from the Science 30 Textbook CD.

step 2: Complete the fourth column of the spreadsheet, Per Capita Energy Use.

step 3: Graph the following:

- the world energy use from 1850 to 2000
- the world population from 1850 to 2000
- the per capita energy use from 1850 to 2000

Analysis

Science Skills
✓ Analyzing and Interpreting

1. Consider the graph of world energy use from 1850 to 2000.

a. Describe the trend in world energy use.

b. Based on the trend, extrapolate your graph to the year 2050.

c. Explain why you extrapolated your graph the way you did. List the factors you considered.

d. How certain are you that your projection of energy use from the present to the year 2050 is reasonable?

2. Consider the graph of world population from 1850 to 2000.

a. Describe the trend in world population.

b. Compare and contrast the trends on the graphs of world energy use and world population.

3. Consider the graph of per capita energy use from 1850 to 2000.

a. Describe the trend shown in this graph.

b. Identify when differences to the general trend occur. Suggest a reason for differences to the general trend.

c. List some factors that influence per capita energy use.

4. Explain how the size of the world population affects on energy use.

A Canadian Way of Life

It may not surprise you that the average Canadian enjoys a lifestyle that consumes large quantities of energy. Some of this energy use is necessary to meet basic needs, such as heating homes, providing food, and travelling to and from school or work. A great deal of energy is used to support a quality of life that extends beyond basic needs.

In the early to mid 1990s, new automobile sales shifted significantly from cars to light-duty trucks (e.g., sport-utility vehicles or SUVs).

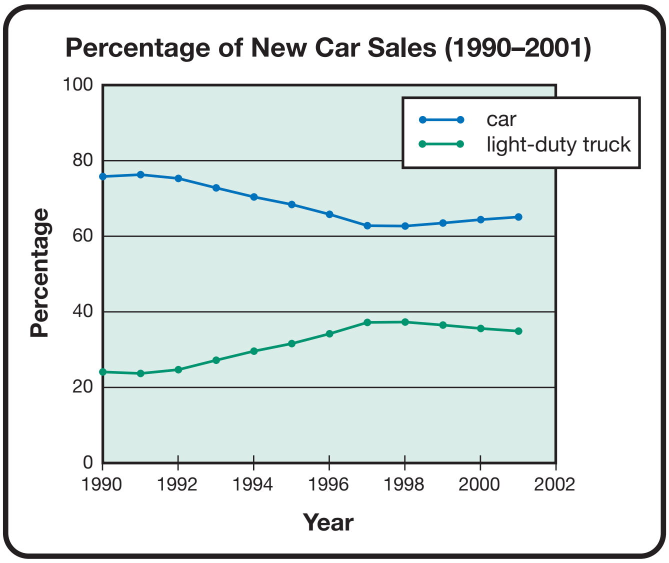


Figure D1.2

Consumers responded strongly to a general perception that driving an SUV brought with it versatility and status. However, these light-duty trucks are less fuel efficient than cars. Between 1990 and 2002, the shift in consumer preference toward SUVs resulted in an increase in energy used for passenger travel. Perception appears to strongly motivate automotive buyers. Even though smaller, more fuel-efficient vehicles are available, Canadians tend to choose heavier, more-powerful automobiles. Many people buying new vehicles are not deterred by the higher energy requirements. It is estimated that an additional $370 per year is spent on fuel for the average SUV. This value will increase as the price of fuel increases.

Practice

Use Figure D1.2 to answer questions 1 to 3.

1. Calculate the change in light-duty-truck sales from 1990 to 1997.

2. Identify reasons used to justify the purchase of light-duty trucks and other larger vehicles.

3. Suggest reasons for the trend in light-duty-truck sales shown after 1997.

Gross Domestic Product (GDP)

The reasons you provided in the answer to Practice question 2 demonstrate some of the attitudes and needs Canadians have regarding their vehicles. These attitudes and needs are, in part, reasons for Canada's large per capita energy use. How does Canada's energy use compare to other countries?

One indicator of a country's economic activity is **gross domestic product (GDP)**. Gross domestic product is measured in billions or trillions of US dollars so that comparisons can be made among countries. As an example, Canada's GDP in 2002 was US$753 billion and Kenya's was US$10 billion. Both countries have similar population sizes, but the total value of all the goods and services produced by Canada is over 75 times greater than that of Kenya. This may not be surprising given that the Kenyan economy is largely agricultural, consisting of major exports of tea and coffee. The Canadian economy, by comparison, includes a great deal of industry—exports of finished products (e.g., motor vehicles, wood products, petroleum products, and telecommunications equipment) and raw materials (e.g., metals and lumber).

Figure D1.3: Farmers' market in Kenya

Industry and the development of natural resources contribute largely to Canada's GDP; but they also use a great deal of energy. A measure of a country's GDP relative to its energy use is called **energy intensity**. Energy intensity is calculated by dividing the energy used by a country in one year by the GDP. Countries with a greater proportion of service and high-tech industries tend to have low energy intensities.

gross domestic product (GDP): the total market value of all goods and services produced by the country in one year; often considered as an indication of a country's economic output

energy intensity: the ratio of energy input (in joules) to economic output (in US$); commonly expressed in terajoules (TJ) per billions of US$ of GDP

DID YOU KNOW?

It takes the energy equivalent of two barrels of oil to produce three barrels of petroleum from oil sand.

Practice

4. Use the following table to calculate the energy intensities for Kenya, Sweden, and Canada.

Country	Energy Use (EJ)	GDP (trillions of US$)
Kenya	0.200	0.010
Sweden	2.22	0.300
Canada	13.80	0.753

5. Compare the energy intensities calculated in question 4. Do these values correspond with the tendency for countries with high-tech economies to have lower energy intensities?
6. Predict the change to Kenya's energy intensity if farmers introduced techniques that increased crop productivity.
7. Suggest reasons why Canada—a developed country—has a high energy intensity.

You will have an opportunity to explore the many factors that affect international energy use in the next activity.

DID YOU KNOW?

On average, developed countries use 7 to 8 times more energy than that of developing countries.

Utilizing Technology

Comparing Energy Use—Canada and Other Countries

Science Skills

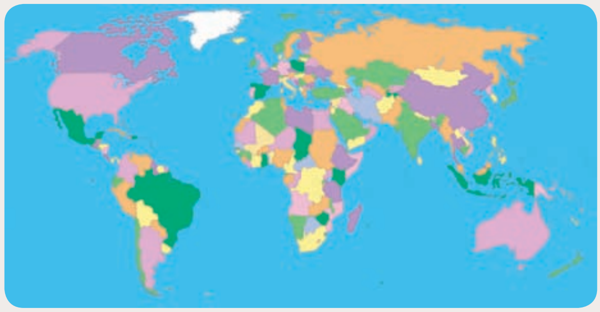
✓ Performing and Recording
✓ Analyzing and Interpreting

Purpose

You will use a spreadsheet to compare the energy used by different countries.

Background Information

A variety of factors, like climate and size of the economy, influence the quantity of energy used by a country.



Pre-Lab Questions

1. List some behaviours of people who live in colder climates. Hypothesize how these behaviours would affect a country's total energy use.
2. State aspects that determine the size of a country's economy.
3. Explain why gross domestic product (GDP) is used to measure the size of a country's economy.

Part A: Energy Use by Country

Procedure

step 1: Open the "Comparing Energy Use" spreadsheet on the Science 30 Textbook CD. Click on the tab labelled "Part A." You should see the "Part A: Energy Use by Country (2002)" table.

step 2: Construct a bar graph showing the total energy use by each country in 2002.

step 3: Construct a bar graph showing the per capita energy use in each country in 2002.

Analysis

4. Consider the graph showing the total energy use by each country in 2002.
   a. Of the countries on your graph, which had the greatest total energy use in 2002?
   b. Which country had the lowest total energy use in 2002?
   c. In 2002, the United States used 2.3 times more energy than China, despite the fact that China's population was 5.5 times larger than the United States's. Provide a reason for this difference.
5. Consider the graph showing the per capita energy use for each country in 2002.
   a. Of the countries on your graph, which had the greatest per capita energy use in 2002?
   b. State possible reasons for Canada having a higher per capita energy use than the United States.
   c. State one advantage of having data describing per capita energy use in addition to total energy use when comparing energy use by countries.

Part B: Effect of Climate on Energy Use

Procedure

step 1: In the "Comparing Energy Use" spreadsheet, select the tab labelled "Part B." You should see the "Part B: Effect of Climate on Energy Use (2002)" table.

step 2: Construct a graph showing the per capita energy use on the vertical axis and average annual temperature of each country's capital city on the horizontal axis.

step 3: Add a linear line of best fit to your graph by selecting "Add Trend line" in the Chart menu. **Note:** This menu only appears when you click on the graph.

Analysis

6. Describe the general relationship between per capita energy use and average annual temperature of a country's capital city.
7. State a generalization about the level of economic development of the countries positioned above and below the line of best fit.
8. Berlin has the same average annual temperature as Ottawa, yet Germany's per capita energy use is less than half that of Canada's. Suggest reasons for the difference in per capita energy use between these two countries.
9. Identify two limitations of any conclusions made from studying this data.

Part C: Effect of Size of Economy on Energy Use

Procedure

step 1: In the "Comparing Energy Use" spreadsheet, select the tab labelled "Part C." You should see the "Part C: Effect of Size of Economy on Energy Use (2002)" table.

step 2: Construct a graph showing each country's GDP (in trillions of US$) on the horizontal axis and the total energy use on the vertical axis.

step 3: Draw a linear line of best fit on your graph.

step 4: Calculate each country's energy intensity (in EJ/trillion of US$), filling in the appropriate column in the table.

step 5: Construct a bar graph showing each country's energy intensity (in EJ/trillion of US$).

Analysis

10. Describe the general relationship between total energy use and GDP.
11. State a generalization about the level of economic development of the countries positioned above and below the line of best fit on your graph.
12. Identify which country has the highest energy intensity. Provide a possible explanation as to why this country's value is the highest.
13. Compare the energy intensity of Canada to those of the United States and Japan. Suggest reasons for the differences in energy intensity between these three countries.

Factors Affecting Energy Use

Climate

As you found in the last activity, there is a relationship between climate and energy use. People who live in cooler climates, like Canada and Russia, use energy to heat their homes. However, people who live in warmer countries, like Australia, use energy to cool their homes. In fact, the most important aspect of climate that influences energy use is extremes in temperature. For example, in Canada in 2002, a cooler than usual winter and warmer than usual summer caused a 47.9-PJ increase in the amount of energy used to heat and cool homes. For comparison purposes, one petajoule (PJ) is approximately the quantity of energy needed to meet the needs of a town of 3800 people for one year.

Figure D1.4: Factors including colder weather and reduced daylight during winter influence energy use in Canada.

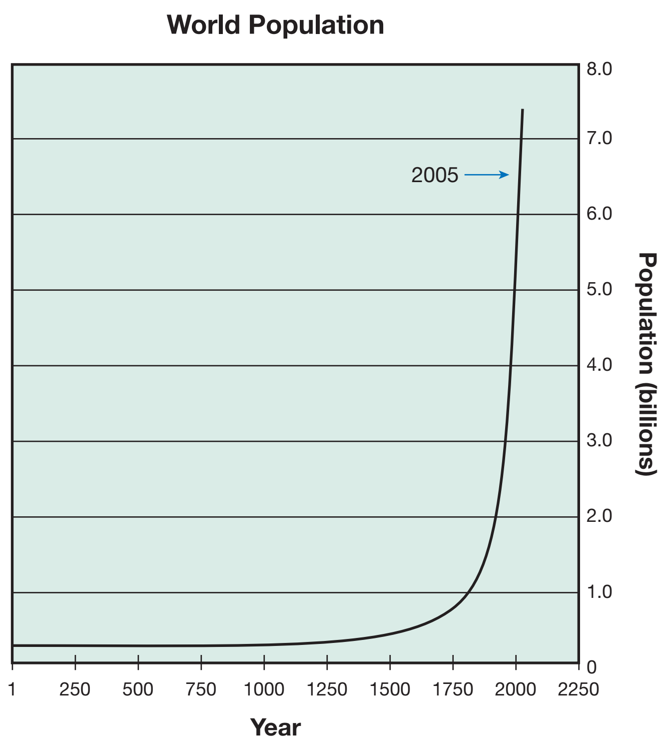
Activity

The term *activity* refers to how much work is being done. For many industries, activity can be measured in terms of tonnes of steel manufactured or number of cars produced. In other parts of Canada, activity has to be measured using other criteria. The financial industry is an important part of Canada's economy, and its activity is measured by dollars made from investments. Activity in the transportation sector is measured by how many kilometres are travelled. Regardless of how you measure activity within an economy, energy is required to maintain it.

Earlier, you learned that the total economic value of a country's industrial activity is measured as gross domestic product (GDP). Countries that enjoy a high standard of living tend to have thriving economies and large GDPs. In Part C of the "Comparing Energy Use—Canada and Other Countries" activity, you saw that the United States has the world's largest GDP. It should not surprise you to recall that the United States, which has the highest economic activity, also has the largest total energy use. Since Canada has a much smaller economy than the US, it has a smaller GDP in addition to a lower total energy use.

Population

Regardless of other measures of a country's economy, per capita energy use is a valuable measure of a country's level of prosperity. The goal of many developing countries is to industrialize and improve the standard of living for its citizens. As you have seen, in order to meet these goals, developing countries will also become larger users of energy and of natural resources (e.g., coal, oil, and natural gas) that can be combusted to supply energy. Recall that increasing the standard of living often requires an increase in the energy use per capita. Many developing countries have large populations, drastically increasing the energy required to meet these goals. Improvement to the standard of living may not only cause total energy use to rise drastically; it may also adversely affect the environment if the consequences are not considered.



DID YOU KNOW?

Service-sector industries that are less energy intensive include communications, banking, insurance, real estate, education, and health care. Also included are the manufacturing of computers, electronics, and machinery.

Science Links

In Unit B, it was determined that acid deposition and particulate pollution are some of the consequences from the use of technology that involves the combustion of fossil fuels for energy production. Later in this unit you will study alternative energy sources and technologies that may help to meet global energy demands while preserving the environment.

Energy Intensity

Figure D1.5: Large equipment and extensive pipelines (shown left) are costly parts of the process to produce petroleum from oil sand. Manufacturing silicone wafers for computer chips (shown right) is a much lower energy-intensive process.

Industry involved with the extraction, refining, or development of natural resources are often highly energy intensive—they require more energy for every dollar of economic output. Whether it is forestry, coal mining, or oil sand development, large equipment and high costs for transporting the materials increase the value for energy intensity compared to other industries. In the “Comparing Energy Use—Canada and Other Countries” activity, you saw that development of Canada’s plentiful natural resources resulted in a higher energy intensity compared to other industrialized countries, like the United States, Germany, and Japan. However, since 1990, the percentage of Canada’s economy composed of energy-intensive industries has been decreasing, shifting toward a less energy-intensive economy.

DID YOU KNOW?

Tires for the trucks used to haul oil sand cost about $50 000 each.

Practice

8. The energy intensities of Canada and Germany in 2002 were 18 and 6 (in EJ/trillion US$ of GDP), respectively. Use the Internet to identify and compare Canada’s and Germany’s major exports. Explain how the differences among exports support the different energy intensities of these two countries.

Energy Efficiency

ENERGY STAR

Figure D1.6: The Energy Star symbol identifies the most energy-efficient appliances available.

Every time energy is used, some of it is transformed. The proportion transformed into a desired form is called **useful output energy**. Do you recall a demonstration in Unit C where the energies of different forms of electromagnetic radiation emitted by a light bulb were measured? In this demonstration, electrical energy was the **input energy** to the light bulb and visible light was considered the useful output energy of this energy conversion. In the demonstration a large amount of non-visible radiation was detected, including infrared (often called thermal energy). The **energy efficiency** of a light bulb is determined by the proportion of input energy that is converted into visible light and not into other forms of energy. For all devices that convert energy, some energy is always lost as thermal energy. Energy efficiency is often represented as a percentage of input energy that has been transformed into useful output energy.

$$\text{energy efficiency} = \frac{\text{useful output energy}}{\text{input energy}} \times 100\%$$

The types of input and output energies vary with the device. Refer to the "Input and Output Energy for Some Energy-Converting Devices" table.

useful output energy: the desired energy form resulting from a process involving a transformation of energy

input energy: the form of energy entering into a process involving a transformation of energy

energy efficiency: the percentage of input energy that has been transformed into useful output energy

INPUT AND OUTPUT ENERGY FOR SOME ENERGY-CONVERTING DEVICES

Device	Input Energy	Useful Output Energy	Waste Energy
light bulb	electrical	visible light	non-visible EMR, such as infrared (heat)
car engine	chemical potential (gasoline)	kinetic	thermal
oven	electrical	thermal energy transferred to food	thermal energy not transferred to food
television	electrical	visible light	non-visible EMR, thermal

Practice

9. Calculate the energy efficiency of a water heater that uses 200 J of energy to increase the thermal energy of water 55 J.
10. If an automobile engine is 20% efficient, calculate the useful output energy from 1 kg of gasoline containing 44.5 MJ of chemical potential energy.

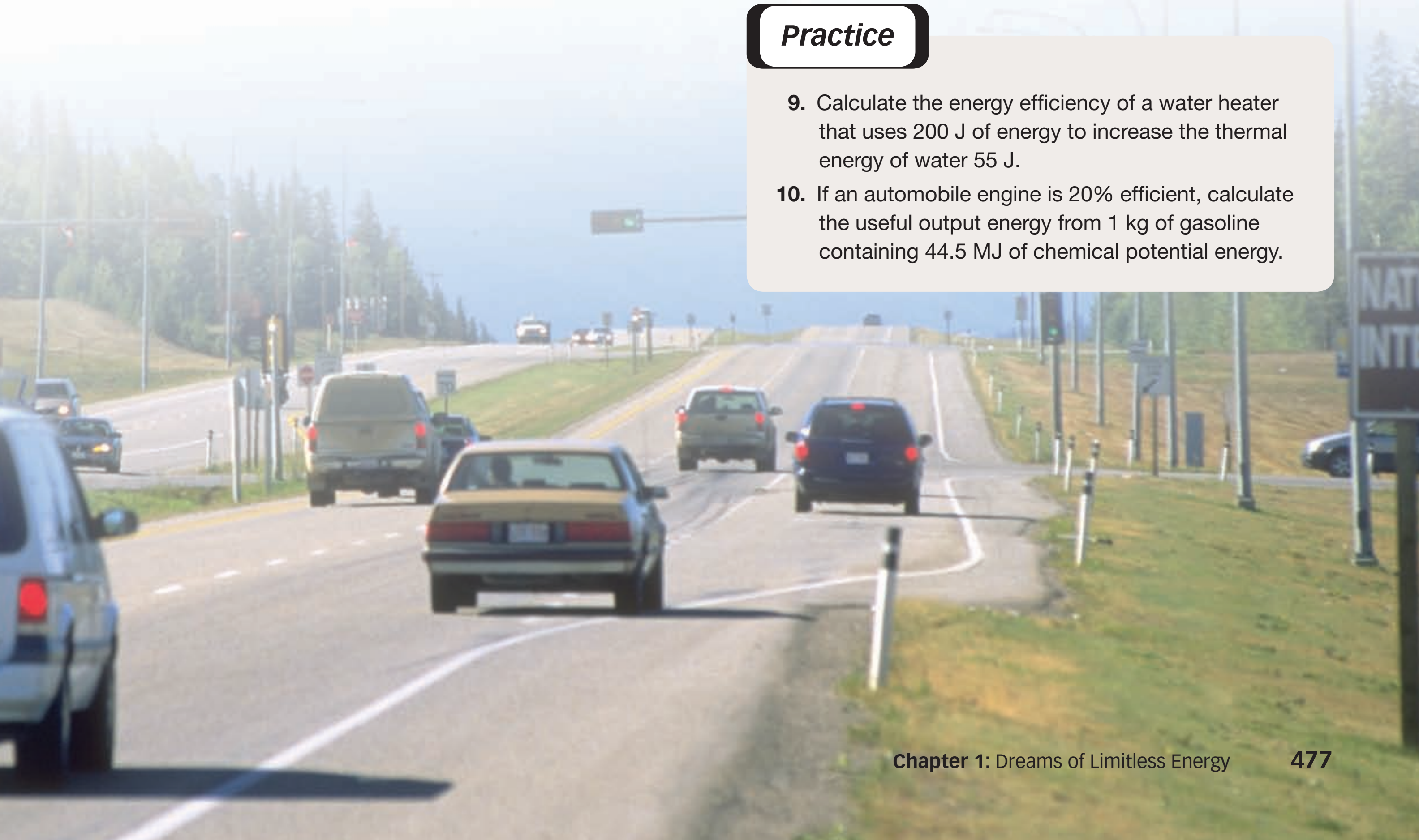


Figure D1.7: The 60-W incandescent light bulb (left) and the 17-W compact fluorescent light bulb (right) produce the same quantity of useful output energy but with greatly different efficiencies. Legislation in Canada will ban the sale of incandescent light bulbs by 2012.

When selecting a replacement bulb for the lamp beside your desk, you may have considered the power rating of the bulbs you had to choose from. Although a 60-W light bulb is not as bright as a 100-W light bulb—the bulb with the higher energy requirement—both devices have similar efficiencies. If you had the chance to consider using a compact fluorescent bulb, you may have noticed that it has a considerably lower power rating (17 W); and it provides the equivalent amount of light as a 60-W incandescent bulb. The drastic reduction in input energy to produce the same quantity of useful output energy is the result of increased efficiency of compact fluorescent lights compared with incandescent bulbs.

Practice

11. Using power ratings, determine the percentage of the total power required by a compact fluorescent bulb versus the total power required by an incandescent light bulb that provides similar output energy.

12. Improvements to energy efficiency from 1990–2003 were estimated to be 883 PJ. If the estimated energy requirement of a small town is 47.9 PJ, calculate the energy saved in terms of the number of additional towns that could have their energy needs met due to improvements in efficiency.

Science Links

Compact fluorescent lights contain trace amounts of mercury. If improperly disposed of, mercury may collect in landfills. Despite this risk, the increased efficiency of compact fluorescent lights could result in an overall reduction in mercury released into the environment from the combustion of coal. Unit B provides further information regarding the effects of mercury and other heavy metals within ecosystems and the effects of other by-products from the combustion of coal.

The use of more efficient electrical devices and other technologies, including the replacement of incandescent lights with compact fluorescent lights, is an important way to offset the increasing need for energy. For example, since 1990, the use of computers in Canadian workplaces has increased 73%, but the energy used by these devices as a whole only increased by 50%. The energy savings of 23% was the result of improvements in the energy efficiency of computers during this time. Improvements in efficiency can also occur in large industry. In fact, between 1990 and 2002, energy use in Canada’s mining industry decreased by 12%. This was mostly due to improvements that made processes more energy efficient.

Figure D1.8: A worker operates a remote-control scoop tram at the Rabbit Lake mine in northern Saskatchewan.

DID YOU KNOW?

The Athabasca Basin in northern Saskatchewan is home to the world’s richest, high-grade uranium mines. Although there are some open-pit facilities, the most productive operations use deep shafts to provide access to the uranium ore found hundreds of metres below the surface. The person shown in Figure D1.8 is working approximately 400 m underground.

Alberta's Energy-Based Economy

Within Canada, Alberta is known for its development of non-renewable energy resources of coal, petroleum, and natural gas. Alberta, however, also produces energy through renewable resources, like wind and hydro. The role of the energy industry is vital to Alberta's economy. Fossil fuels make up over half of the province's exports. In addition, **royalties** paid to the Alberta government by energy companies that extract and process natural resources account for about one-third of the province's total revenue. Also, nearly one in six workers in Alberta is employed, either directly or indirectly, by the energy sector.

royalty: money paid to the government that is a share of the profits made from the development of a natural resource

Figure D1.9: Many refineries are located near Edmonton and Fort Saskatchewan and are involved in processing petroleum or its components.

Although Alberta has an abundance of energy resources, the processes used to extract and process coal, natural gas, and petroleum are very energy intensive. Figure D1.10 shows the 2003 per capita energy use in Canada. Notice that Alberta's per capita energy use is two-and-a-half times greater than the national average.

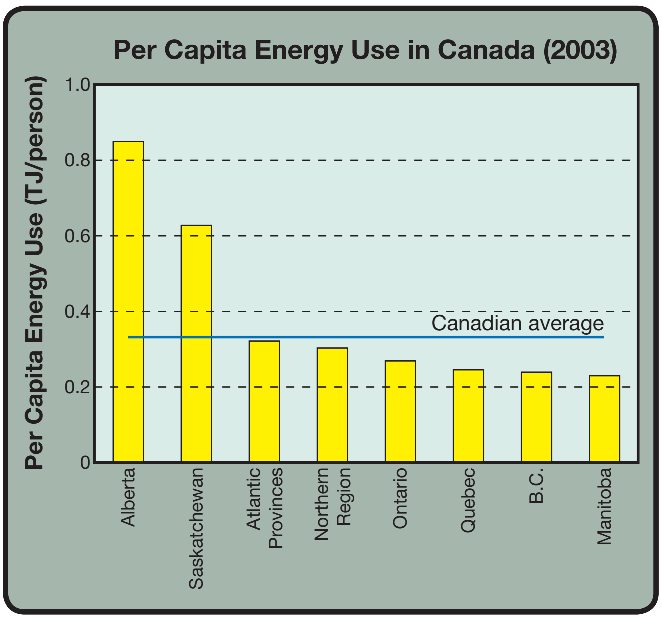


Figure D1.10

1.1 Summary

Energy use is on the rise globally due to exponential population growth and increasing development. Canada is a major contributor to global energy production and energy use, and it is one of the developed world's largest per capita energy users. Factors that affect energy use by countries include climate, size of economy, economic diversity, level of technology, and efficiency in the conversion of energy.

1.1 Questions

Knowledge

1. Identify considerations, apart from energy use, that influence decisions about the purchase of products.
2. Describe the trend of the world's energy use from 1850 to the present.
3. Define *per capita* and *gross domestic product* (*GDP*).
4. State an example of how a change in consumer preference led to an increase in the quantity of energy used by Canadians for transporting both people and products.
5. List five factors that affect energy use. Provide definitions for each factor.
6. Describe the relationship between the size of a country's economy (as measured by GDP) and its total energy use.

Applying Concepts

7. The United States is Canada's largest trading partner and shares many similarities in terms of lifestyle and culture.
   - **a.** Compare the total energy consumption of Canada to that of the United States.
   - **b.** Compare the per capita energy use of Canada to that of the United States.
   - **c.** Provide reasons for the differences between the per capita energy use of these two countries.

Use the following information to answer questions 8 and 9.

This table summarizes the average Canadian's energy use for various activities as a percentage of total daily energy use.

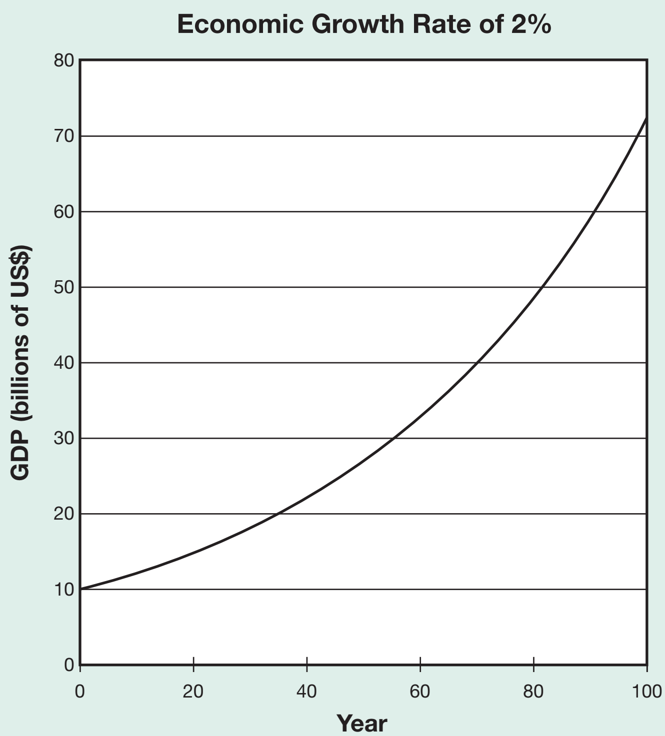
Household Item	End-Use of Energy (% of total daily energy use)
furnace/air conditioner	45
water heater	11
washer and dryer	10
lighting	7
refrigerator	6
TV, VCR, DVD	2
computer	2
dishwasher	2
other	15

8. For each household item listed in the table, suggest one action that would reduce personal energy use.

9. Describe how you would develop an experiment or a study to determine the effect of making the changes suggested in question 8. State any data or information you would need to complete this experiment or study.

Use the following information to answer questions 10 to 12.

A yearly increase of 2% in GDP is considered to be an indicator of a healthy economy. The graph given shows an economy growing at a constant rate of 2% per year for 100 years.



10. Describe the pattern of change in GDP over the time shown on the graph.

11. Discuss the implications that this type of economic growth would have in terms of total energy use.

12. Identify an important strategy for reducing energy use that would counteract an increasing energy demand.